Energy Management in Commercial Buildings

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal, energy conservation and renewable energy and conventional energy resources. Administration for the program is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page eight.

Energy Management in Commercial Buildings

The various types of equipment used in modern buildings for purposes of heating, ventilation and air conditioning (HVAC) consume sizeable amounts of energy while providing a comfortable indoor environment for people. Because this energy, in the form of electricity or fuel, represents a significant portion of the overall costs to operate and maintain commercial buildings, the owners and managers of these facilities would like to reduce their energy costs without having to sacrifice indoor comfort level. If possible, they would like to make their office buildings, industrial plants and institutions even more comfortable.

Although an established industry already exists which offers a variety of services and equipment designed to provide better control and management of building environments, there is still room for new and innovative control devices and energy management strategies in Alberta, and Canadian, buildings. For this reason, several research, development and demonstration projects aimed at cost-effective management of energy in commercial buildings were funded by A/CERRF.

While the objectives of each of these projects differed, they all shared common goals of developing devices or control strategies that not only save energy without sacrificing comfort but also do not complicate the work habits of building maintenance personnel. They were designed for users who prefer techniques that are simple to understand and do not require extensive operator training before they can be used.

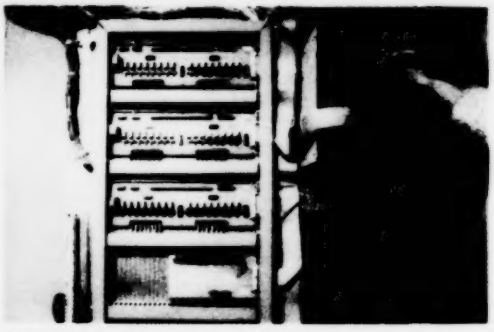
An Interactive Building Management System

Although maintenance and operating costs can be reduced, and energy can be saved, if the environmental systems of a building are properly managed and controlled, most of the existing computerized control systems available on the market are expensive and complicated. Furthermore, they have been developed primarily for large buildings. While less expensive systems are available for small buildings, they lack flexibility.

Because there is a need for an easy-to-use, computerized building control system that is inexpensive and reliable and can be used in buildings of various size, A/CERRF funded the development of such a system by MLW Interspace Automation Ltd. of Edmonton.

The system, which is based on readily available microprocessor technology, consists of a remote programmable controller and a control and monitoring station that uses a desktop computer. Initially, software for the system was developed around Apple II computers but plans call for conversion of the software to allow control of the system by IBM PC computers.

The individual components of the system can be interconnected by cable within a building or by telephone lines when they are remotely located. The modular concept used in the design allows monitoring and control of a large number of buildings by one remote control centre or the interconnection of up to 99 remote programmable controllers for large applications.

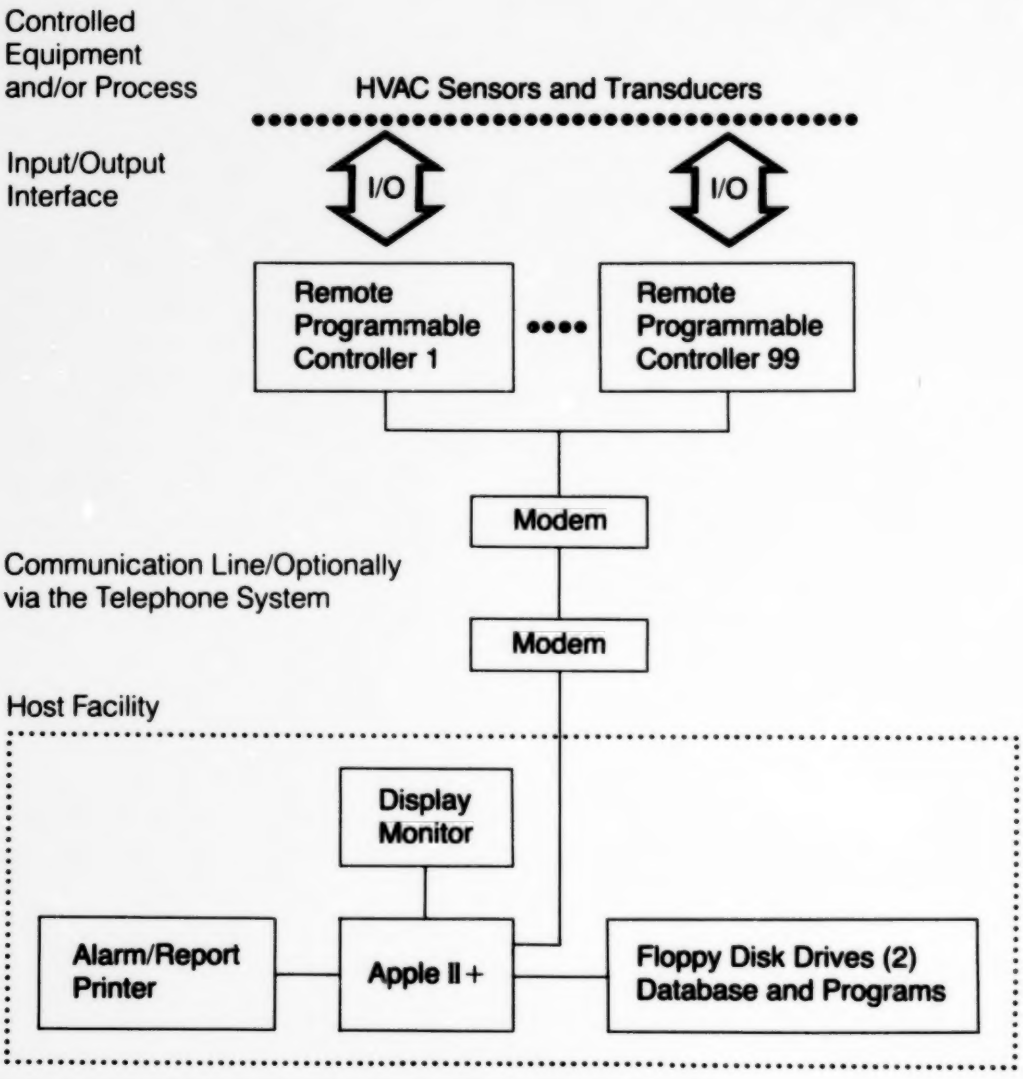


Remote programmable unit installed in a multi-purpose building is one component of INTEGRATION 1 system

The system, known as INTEGRATION 1, has control capabilities which can result in energy cost savings of 25 to 30 per cent more than can be expected from control systems that employ pneumatic components. All application functions can be configured with interactive software, which eliminates the time-consuming edit/compile procedures that are required in many existing control systems.

INTEGRATION 1 also has menu-driven, on-line prompting and extensive error-checking features which make it simple to operate, even for those people who have no special computer programming experience. Operators can use it competently after only four hours of classroom instruction.

Block Diagram of "INTEGRATION 1" System



(Source: *"INTEGRATION 1": User-Friendly Computerized Building Management System*, L. Wong, April 1986)

After a prototype unit was built in 1984/85, a production model was assembled and installed in a multi-purpose building owned by the City of Edmonton. The 52 000 square foot (4 680 m^2) structure contains two offices, three storage areas, two workshops and a sizeable garage for municipal vehicles.

Environmental systems in this 52 000 square foot (4 680 m^2) building were controlled by INTEGRATION 1

During a three-month demonstration period over the winter of 1985/86, the system controlled 18 unit heaters, seven roof-top heating and cooling units, five exhaust fans, one central HVAC system and the electricity supplied to automobile plug-ins.

One of the control techniques used during this demonstration was start/stop scheduling to reduce electrical loads when the building was unoccupied, which was done through measures such as duty cycling of the HVAC equipment. Altogether, 71 control and monitoring "points" within the building were interconnected with INTEGRATION 1.

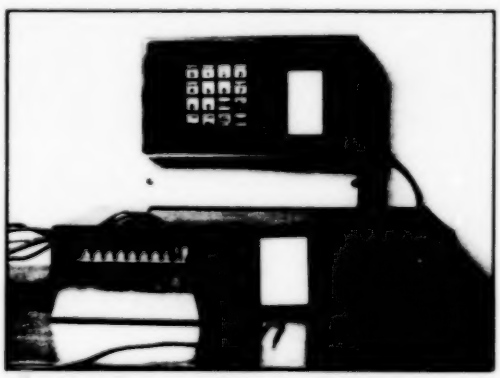
From mid-December, 1985 to mid-March, 1986 while the building was under control of the system, natural gas consumption was reduced by 40 to 50 per cent versus the same period one year earlier after correction for degree days. Similarly, electricity costs were reduced by 10 to 20 per cent, even though night-time use of the building was unusually high, which caused more electricity than normal to be used for that time of year.

A two-year payback was projected for this particular application with the cost per point calculated at $275 versus $500 for other control systems.

Multizone Setback Thermostat

Because everyone senses heat differently, air inside a building that feels warm to one person may seem cool to someone else. One way to accommodate this phenomenon is to subdivide buildings into individual offices or work zones and then separately control the air temperature in each zone.

To do this, each zone must be provided with its own air supply duct and damper and some means of changing the volume of ventilation air in the controlled zones to achieve desired air temperature. By supplying each zone with its own thermostat, desired comfort levels can be achieved, but during unoccupied periods it is difficult to save any energy. If simple on-off timers are used to control the cooling system, some energy can be saved but the approach becomes inflexible whenever there is a need for people to occupy the building outside normal working hours. A more sophisticated level of control can result if dampers are able to respond directly to changes in air temperature in each zone.



The MZT 1000 Multizone Setback Thermostat System is comprised of a central controller, temperature sensors and damper controllers

A multizone setback thermostat and controller, called the MZT 1000, was developed by Daxcom Electronics Inc. of Calgary with financial support from A/CERRF. The device can schedule heating and cooling loads for up to 16 zones, each of which can be programmed differently and can be assigned up to four different temperature setpoints within any 24-hour period. Also, it is possible to select different temperature settings for days when zones are occupied as opposed to being vacant, such as on weekends and during holidays. Furthermore, the controller can be used with electric dampers or pneumatically controlled dampers or any combination of the two, making it possible

to use the controller with any existing constant air and/or variable air volume system. This is accomplished by having separate damper controls for each zone and not including them within the body of the central controller. This reduces the size and the cost of the central control unit.

The control system is comprised of a small (26 cm x 21 cm x 11 cm) wall-mounted central controller in a transparent housing which receives operator instructions by way of a 14-function keypad.

Once every 16 seconds, the controller interrogates temperature sensors installed in each zone. This allows it to measure zone temperatures to an accuracy of ±1°C. The unit operates on 24 volts AC and has battery standby for computer memory.

Also connected to the central controller are damper controllers which are mounted near the damper motors. There is one damper controller for each comfort zone.

The MZT 1000 is as easy to operate as a pocket calculator. After the time of day and temperature setpoints for each zone have been entered into the microprocessor, the unit will function without operator intervention.

For example, whenever the sensed temperature in a zone has reached a low setpoint chosen for that particular time period, the controller will cause dampers to progressively close and obstruct the flow of cooled air, thereby maintaining the temperature at a preset value. Conversely, if the temperature begins to rise, the controller will direct the damper to open until the desired temperature has been restored. This reduces cooling air requirements, fan horsepower and chiller horsepower, thus producing energy savings.

Market surveys indicated that the MZT 1000 is particularly appropriate for existing buildings which are to be retrofitted to reduce energy consumption. Although field demonstrations of the unit were not possible during the period when A/CERRF funds were being provided, bench testing has shown that it is a reliable system which should be capable of a two-year payback in many installations.

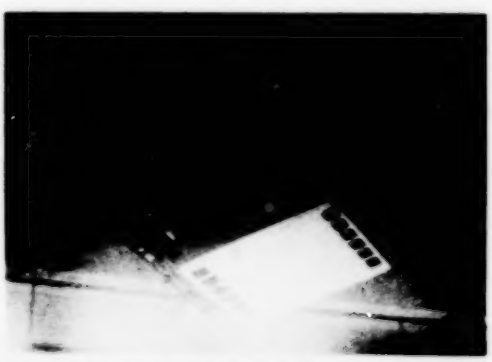
Energy Management in Small Buildings

It has been estimated that 95 per cent of small businesses in Alberta occupy leased premises, and approximately half of them have three-year lease agreements. This makes it difficult for small business owners to justify the capital costs of energy-saving devices when payback periods exceed two years.

To demonstrate that small energy users can achieve energy cost savings within reasonable periods of time, an energy management project was initiated in a 14 000 square foot (1 260 m²) warehouse heated by nine ceiling-mounted unit heaters. The building included a 1 400 square foot (126 m²) office area heated by a separate roof-top unit.

A Modicon Micro 84 programmable controller was used to cycle the heaters on and off according to a schedule which varied according to the time of day. During normal working hours, five of the unit heaters were cycled on one schedule while the other four units were cycled on a different schedule to achieve an ambient temperature of 72°F (22.2°C). At night and on weekends, a lower ambient temperature of 52°F (16.7°C) was maintained. The roof-top unit was also operated on a set schedule. At all times a fail-safe thermostat set at 46°F (7.8°C) kept the warehouse temperature from falling too low.

The warehouse temperature was controlled in this manner for two years. Records of natural gas consumption were compared with records from the three-year period immediately preceding the demonstration.



Duty cycling of ceiling-mounted unit heaters, like this one, was achieved with a programmable controller.

Assuming a constant fuel cost of $2.60 per gigajoule, costs corrected for degree days averaged $0.90 per degree day prior to the test period, but they fell to $0.64 per degree day during the demonstration.

The total cost of the developed system was $1695. Taking into account variations in annual energy consumption at this particular location, the payback period ranged from 15 months to 21 months. The system, therefore, should be attractive to small business owners, particularly in view of the fact that warehouse staff said their surroundings were as comfortable during the test as they had been prior to the demonstration.

Interactive Computer Simulation of Building Mechanical Systems

If any process control scheme is to be successful, it is essential that operators associated with it be motivated and well-trained. This is true in petrochemical plants and it is just as true in high-rise office buildings where property management and building maintenance staff need to be properly trained to use energy-saving devices and strategies in their daily operation of HVAC systems.

To provide training for operators in proper methods of controlling environmental conditions within buildings, while achieving optimal energy-efficiency and cost-effectiveness, a series of graphical interactive computer simulations of air-handling systems commonly found in commercial and industrial buildings was developed at Southern Alberta Institute of Technology (SAIT) in Calgary.

The concepts, control techniques, advantages and disadvantages of the following HVAC configurations were simulated:

- a single duct, constant volume, variable temperature air handling system
- a single duct, variable volume, constant temperature system
- a multi-zone, constant volume, variable temperature system
- a dual duct, constant volume, variable temperature system

Also, simulations were developed for the following individual components of building control systems:

- a multi-stage centrifugal chiller
- basic control loop
- load shedding and duty-cycling

Software and hardware components were developed to allow interactive computer simulations of some building mechanical systems.

Early on in the project, it was decided that software would not be developed specifically for one brand of microcomputer because to do otherwise would limit market potential and would assume that production of the computer would not be discontinued in the future. Also, it was decided that software would not be developed for every type of microcomputer on the market because that would involve substantial development costs. Furthermore, it was recognized that commercially available hardware is designed to handle a variety of customer requirements — from word processing to production of financial reports — but, for simulation purposes, a less complicated computer is all that is needed. Therefore, along with software development, the SAIT project team designed and built a microcomputer especially suited for simulation work.

As designs for the hardware evolved, it was recognized that prospective users are not accomplished typists nor was it necessary for them to use a standard typewriter keyboard. Instead, an inexpensive eight-key, color-coded keyboard was designed which is as easy to use as a home video game. Using a technique known as "softkey," key functions can be altered through the software. For each simulation a legend, that appears at the bottom of the screen and is color-coded to correspond with the colors of the keys, specifies the key functions for that particular exercise. This approach to user-friendliness eliminates the need for a printed operator's manual. It also allows keys to be labelled with universal symbols or foreign language characters to allow the system to penetrate overseas markets.

The hardware has been packaged in a robust case to allow it to be shipped for distance learning situations. To use it, a self-teaching student would simply connect it to a conventional television set and turn it on. At this point, the simulation would take over and provide all necessary instructions on the monitor screen.

The simulations allow an operator to experiment with particular systems, to learn about the function of each component in the system and its relationships to the system as a whole and to place the simulated system in extreme operating conditions that could be costly or dangerous in real life.

Simulations can be designed to permit random faults to occur. From this, experience can be gained in analysis of control systems and in troubleshooting. By changing the environmental conditions that occur either outside or inside the building, it is possible to test an operator's skill in controlling the HVAC system in an energy-conserving and cost-effective manner while maintaining adequate comfort conditions within the building.

So far, efforts to promote and market the simulation system have generated enthusiastic interest on the part of educational institutes and organizations representing building owners and property managers.

To obtain more information about the projects described herein, the following researchers should be contacted:

1. Specifics concerning the "Integration 1" building management system should be obtained from:

   Lim Wong, P.Eng.
   MLW Interspace Automation Ltd.
   17203 - 102 Street
   Edmonton, Alberta
   T5X 3X5

   Telephone: (403) 456-5549

2. The "MZT 1000" multizone thermostat and controller was developed by:

   Jorma Ponka, P.Eng.
   Daxcom Electronics Inc.
   3525 - 62nd Avenue, S.E.
   Calgary, Alberta
   T2C 1P5

   Telephone: (403) 236-9101

3. The energy management system for small buildings was demonstrated by:

   Gary Whitaker
   Whitaco Holdings Ltd.
   11615 - 163 Street
   Edmonton, Alberta
   T5M 3W6

   Telephone: (403) 455-4141

4. Interactive graphical computer simulations of building mechanical systems were developed at Southern Alberta Institute of Technology. For more information, contact:

   Owen B. Baker
   Department Head
   Power Engineering Department
   Southern Alberta Institute of Technology
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